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LINEAR INFINITE-DIMEN. (U) FLORIDA UNIV GAINESVILLE
DEPT OF ELECTRICAL ENGINEERING E W KAMEN NOV 82
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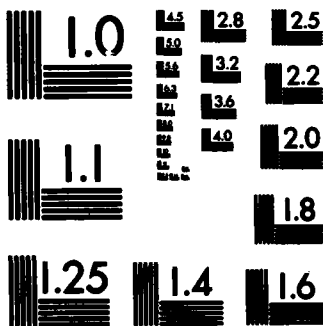
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 13162.10-MA; 17589.3-MA	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Algebraic Theory of Linear Time-Varying Systems and Linear Infinite-Dimensional Systems		5. TYPE OF REPORT & PERIOD COVERED Final: 1 Feb 78 - 31 Aug 81
7. AUTHOR(s) Edward W. Kamen		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Florida Gainesville, FL 32611		8. CONTRACT OR GRANT NUMBER(s) DAAG29 78 G 0063 DAAG29 80 K 0076
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office Post Office Box 12211 Research Triangle Park, NC 27709		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE Nov 82
		13. NUMBER OF PAGES 5
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) NIA		
18. SUPPLEMENTARY NOTES The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) linear systems time varying systems infinite dimensional systems algebra		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The research centered on two major classes of linear systems: Linear time-varying systems and linear infinite-dimensional systems. A brief description of the work which has been carried out on each class of systems is given.		

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ALGEBRAIC THEORY OF LINEAR TIME-VARYING SYSTEMS
AND LINEAR INFINITE-DIMENSIONAL SYSTEMS

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November 1982

Final Report on U. S. Army Research Grant No. DAAG29-78-G-0063

Covering the period:

1 February 1978 through 31 May 1980

Prepared for:

U. S. Army Research Office
P. O. Box 12211
Research Triangle Park, NC 27709



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1. Summary of Research

The research centered on two major classes of linear systems: Linear time-varying systems and linear infinite-dimensional systems. A brief description of the work which has been carried out on each class of systems is given below.

1.1 Linear time-Varying Systems

A fairly complete theory of realization was developed for the class of input/output maps given by an analytic weighting pattern (Green's function). Necessary and sufficient conditions were derived for the existence of a realization given by a first-order vector differential equation with analytic coefficients. In particular, it was shown that realizability is equivalent to the finiteness of modules (defined over a ring of real analytic functions) generated from the weighting pattern. The work has resulted in the first general procedure for computing minimal realizations. The procedure is based on a method for computing bases for finite free modules defined over a Bezout domain. These results have also been utilized to yield a systematic procedure for reducing a given state-equation representation in order to construct a minimal state model. Minimal models have desirable dynamical properties which are very useful in control and estimation problems, and thus the ability to reduce a given model should prove to be very useful in a wide range of applications. A complete description of this work can be found in reference [5] in the list of research papers.

1.2 Linear Infinite-Dimensional Systems

The second part of the work dealt with various classes of linear infinite-dimensional systems including lumped-distributed networks (e.g., lumped networks with LC or RC transmission lines), systems with time delays, multi-dimensional systems, and linear infinite-dimensional discrete-time systems. It was discovered that due to similarities between these classes of systems/networks, some techniques are

applicable to all four classes of systems and in many instances, results for one class of systems yield corresponding results for the other classes of systems. As an excellent example of this "carry over" of results, it was discovered that results on the stability of two-dimensional systems have a counterpart in the theory of linear systems with time delays. More precisely, we were able to define a notion of "two-dimensional" stability for systems with time delays, which turned out to be very closely related to the notion of stability independent of delay. A very important feature of the new stability concept is that it can be checked in a finite number of steps, whereas such is not the case for fixed-delay stability. This new concept of stability has turned out to be very useful in the study of feedback control, for example, in the problem of stabilization by feedback.

In addition to linear systems with delays, we also concentrated on linear multi-dimensional systems and linear infinite-dimensional discrete-time systems. These classes of systems arise in applications involving distributed processing, array processing, and parameter-adaptive control. The first phase of the work centered on the development of a control theory based on a Riccati difference equation with coefficients in a commutative Banach algebra. Necessary and sufficient conditions for the existence of solutions to the (generalized) Riccati equation have been obtained. These results have been utilized in the study of stabilization by feedback. For details on this work and the work on systems with time delays, please refer to references [1], [6], [7], [8], and [9] in the list of research papers.

2.0 List of Research Papers and Presentations Prepared under Grant

1. E. W. Kamen, "Lectures on algebraic system theory: Linear systems over rings," NASA Contractor Report 3016, NASA Ames Research Center, Moffett Field, California, July 1978.
2. E. W. Kamen, "Control of large discrete-time systems defined over a ring of shift operators," paper presented to 761st Meeting of the American Math. Society, November 1978. Abstract of paper in Notices of the A. M. S., Vol. 25, No. 6, p. A-665, October 1978.
3. E. W. Kamen, "Algebraic aspects of the problem of realization in the time-varying case," paper presented to NATO Advanced Study Institute on Algebraic and Geometric Methods in Linear System Theory, Harvard University, June 1979.
4. E. W. Kamen, "Algebraic approaches to linear functional differential equations," paper presented to Canadian Math. Society Annual Seminar, University of Toronto, July 1979.
5. E. W. Kamen, "New results in realization theory for linear time-varying analytic systems," IEEE Transactions on Automatic Control, Vol. AC-24, pp. 866-878, December 1979.
6. E. W. Kamen, "A note on the representation and realization of lumped-distributed networks, delay-differential systems, and 2-D systems," IEEE Transactions on Circuits and Systems, Vol. CAS-27, pp. 430-432, May 1980.
7. E. W. Kamen, "Linear discrete-time systems over a commutative Banach algebra with applications to two-dimensional systems," in Algebraic and Geometric Methods in Linear Systems Theory, Lectures in Applied Mathematics, Vol. 18, C. Byrnes and C. Martin, Eds., American Math. Society, Providence, pp. 225-237, 1980.
8. E. W. Kamen, "On the relationship between zero criteria for two-variable polynomials and asymptotic stability of delay differential equations," IEEE Transactions on Automatic Control, Vol. AC-25, pp. 983-984, October 1980.
9. W. L. Green and E. W. Kamen, "Stabilizability of linear discrete-time systems defined over a commutative normed algebra," in Proc. 19th IEEE Conference on Decision and Control, Albuquerque, pp. 264-268, December 1980.

3. Scientific Personnel Supported by the Grant

Edward W. Kamen, Principal Investigator

There were no students supported by the grant.

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